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ABSTRACT

This study characterizes the inscriptional practices demonstrated by 7th graders, particularly their use of data tables and graphs, in an inquiry-based learning environment. Drawing on a naturalistic approach, we examined two seventh grade classes during an eight-month instructional unit that emphasized water quality and relevant concepts. We collected and analyzed multiple data sources. The analysis shows that constructing and interpreting graphs and tables provided students with opportunities to discuss, review, and clarify questions about concepts and inquiry process. The level of students' participation in constructing and interpreting practices increased over time. At the end of the water quality unit, students were capable of fully participating in designing a more complicated inscription and interpreting new inscriptions. The analysis also suggests that four features of the learning environments promoted the development of inscription practices: (1) embedding the use of inscriptions in students' science inquiry; (2) providing scaffolds to support students' inquiry process; (3) sequencing tasks and the inquiry process; and (4) engaging students in science inquiry in an iterated manner. This study provides insight into the design of a learning environment in which students can develop competent and authentic scientific practices. (Author)

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Inscriptional Practices in Inquiry-based Classrooms:

How do Seventh Graders Construct and Interpret Data Tables and Graphs?

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Abstract

This study characterizes the inscriptional practices demonstrated by seventh graders, particularly their use of data tables and graphs, in an inquiry-based learning environment. Drawing on a naturalistic approach, we examined two seventh grade classes during an eight-month instructional unit that emphasized water quality and relevant concepts. We collected and analyzed multiple data sources. The analysis shows that constructing and interpreting graphs and tables provided students with opportunities to discuss, review, and clarify questions about concepts and inquiry process. The level of students' participation in constructing and interpreting practices increased over time. At the end of the water quality unit, students were capable of fully participating in designing a more complicated inscription and interpreting new inscriptions. The analysis also suggests that four features of the learning environment promoted the development of inscriptional practices: (1) embedding the use of inscriptions in students' science inquiry, (2) providing scaffolds to support students' inquiry process, (3) sequencing tasks and the inquiry process, and (4) engaging students in science inquiry in an iterated manner. This study provides insight into the design of a learning environment in which students can develop competent and authentic scientific practices.

Inscriptional Practices in Inquiry-based Classrooms:

How do Seventh Graders Construct and Interpret Data Tables and Graphs?

Scientific inscriptions constitute an integral part of science practices (Lemke, 1998).

Graphs, diagrams, data tables, symbols, maps, and models are widely seen in science textbooks and professional articles. These inscriptions are types of transformations that materialize or visualize an entity into another format or mode (Latour, 1987). They convey information, organize data, demonstrate patterns and relationships, and communicate scientific knowledge. Science studies suggest that scientific knowledge and the reality of science are constructed through manipulating a variety of inscriptions (Knorr-Cetina, 1983; Lynch & Woolgar, 1990). Scientific inscriptions not only display the information in a different mode, but also multiply and recreate meanings of the given information that otherwise cannot be realized (Lemke, 1998).

Scientists demonstrate various practices associated with inscriptions. Scientists construct inscriptions to express ideas for a given task, interpret meanings of inscriptions across contexts, use inscriptions to explain phenomena and make predictions, and use various inscriptions for communication (Kozma, Chin, Russell, & Marx, 2000). These various customary ways of using inscriptions are regarded as "inscriptional practices" in this study. A focus on the use of scientific inscription could provide students with opportunities to develop competent scientific practices (Lehrer & Romberg, 1996; Roth & McGinn, 1998), and engage students in authentic scientific tasks (e.g., J. S. Brown, Collins, & Duguid, 1989; Resnick, 1987).

Given the important role of inscriptions in scientific practices, it is unfortunate that many middle school and high school students have difficulties in using, interpreting, and understanding them (Ben-Zvi, Eylon, & Silberstein, 1987; Krajcik, 1991; Leinhardt, Zaslavsky, & Stein, 1990). Empirical studies indicate that students do not demonstrate inscriptional competencies as

scientists do (Kozma & Russell, 1997). Moreover, little is known about how students develop their understandings of inscriptions over time and what resources or features of the learning environment support students to do so.

Drawing on a naturalistic approach (Lincoln & Guba, 1985; Moschkovich & Brenner, 2000), this study characterizes the inscriptional practices demonstrated by seventh graders, particularly their use of data tables and graphs, during an eight-month instructional unit in an inquiry-based learning environment. The following research questions guided the study: (1) What characterizes the inscriptional practices of seventh graders when they construct and interpret data tables and graphs? (2) How do students' inscriptional practices change over time? (3) What aspects of the learning environment help students develop inscriptional practices?

Several reasons guided our decision to focus on middle school students' inscriptional practices with data tables and graphs. First, many scientific inscriptions such as graphs, data tables, and chemical equations are formally introduced to students at the middle school level. To find out possible sources of students' difficulties in learning these inscriptions, researchers need to study how middle school students learn scientific inscriptions in classrooms. Second, in middle schools, students begin to experience the complexity of the scientific inquiry process (Krajcik et al., 1998) that provides for meaningful context to engage in scientific practices. It is important for researchers to understand the interactions between the design of a learning environment and the development of inscriptional practices. Third, most of the studies that investigated students' inscriptional practices have focused on college students (e.g., Bowen, Roth, & McGinn, 1999; Kozma & Russell, 1997). One exception is the study conducted by Roth and Bowen (1994). Yet, Roth and Bowen's study was relatively short-term (three-month) and did not study how students' inscriptional practices are supported by features of a learning

environment. Finally, among the inscriptions used in the instructional units (e.g., data tables, graphs, models, digital pictures, and webpages), data tables and graphs were most practiced; students created and analyzed them three times throughout the unit. The rich data allowed us to characterize students' inscriptional practices, trace students' learning trajectories, and examine the resources and scaffoldings that support students' practices.

Learning Inscriptions as Social Practices

To characterize students' learning process when they construct and use data tables and graphs, this study takes a social practice perspective (Lave, 1988; Lave & Wenger, 1991). This perspective addresses the ongoing, evolving nature of knowledge construction (Roth & McGinn, 1997, 1998) and investigates scientific knowledge before it is concretized as taken-for-granted (Latour, 1987). That is, rather than treating inscriptions as unchangeable knowledge elements for students to learn in a science classroom, the social practice perspective sees inscriptions as sociocultural tools that are co-constructed and changed through interactions among community members and available resources, such as an innovative technological tool and a newly developed theory that members use to carry out a practice (Kozma, 2000b). This perspective helps to study and characterize social interactions among contexts, members, and resources in educational settings (Kelly, Chen, & Crawford, 1998).

Viewing inscriptions as social objects, Roth and his colleagues (Roth & Bowen, 1995; Roth & McGinn, 1997, 1998) argued that inscriptions are ontologically independent of the phenomena they represents. Constructing an inscription is not a simple mapping exercise, and developing competence to represent data by inscriptions (e.g., graphs, spectra, and models) requires a considerable amount of inscriptional practices. However, as inscriptions are traditionally taught as ready-made-science in a science classroom, the social and contextual

factors involved in inscribing activities are combined into a straightforward and self-evident relationship between an inscription and its referent. Without opportunities of experiencing the iterative and social processes in which inscriptions were originally constructed, it is difficult for students to reconstruct the canonical meanings of inscriptions. Therefore, the design of a learning environment should enable students to use inscriptions in open-ended and flexible ways (Greeno & Hall, 1997) and allow students to explore where, when, why, and in what ways inscriptions are used.

Furthermore, inscription-related activities need to be valued within a knowledge-building community. Within a community, not only do members pursue individual meanings to enhance their individual cognition, but they also construct social meanings to become members of a group (Kelly & Chen, 1999). In Roth and Bowen (1995), over a period of seven weeks, students gradually included more and more graphical inscriptions in their reports. The development from less to more abstract inscriptions was accelerated by the teacher or peer requests to present their data in a more convincing way. Roth and Bowen attributed students' competent inscriptional practices, such as translating or mathematizing their physical experiences into graphical representations and using graphing as a strategy to solve problems, to "cultural accomplishment" (p. 98) because through interactions within and between small groups the learning community created a culture (or social norm) that encouraged students to use graphs in their practices. In a learning community, social interactions are not only a catalyst for cognitive development, but also influence the learning products (Cobb & Yackel, 1996), which could be increasingly sophisticated ways of representing scientific knowledge. Teachers and students are community members who create particular ways of talking, thinking, and interacting, which shape and are shaped by their inscriptional activities. Their social interactions and class discourse processes

become rule-driven (Bloome & Egan-Robertson, 1993) to allow and exclude what and how scientific inscriptions are practiced, constructed, and intertextually connected through class interactions (Kelly & Chen, 1999). From this social practice perspective, therefore, meanings of inscriptions and inscriptional activities are co-constructed by community members including students, teachers and sometimes learning tools (Kelly & Crawford, 1996). Some studies have shown that teachers' discursive strategies would play an important role in establishing a culture of classroom that promotes certain class activities to happen (Rex, 2001; Tabak & Reiser, 1999).

Although the metaphor of classroom-as-a-cultural-community provides an explanation of students' increasing use of inscriptions (Roth & McGinn, 1997, 1998), it raises a concern about whether a classroom culture always accelerates the ideal science learning because the classroom culture could match as well as conflict with the culture of a community of scientists (Kelly & Green, 1998). Given that science educators wish to engage students in the practices of scientists (J. S. Brown et al., 1989), social norms or a classroom culture should be guided or constrained by the disciplinary culture of science. However, as Roth and McGinn (1997, 1998) described, it is unclear how social norms in a learning community are developed towards those of a community of scientists, even though a comprehensive use of inscriptions is part of the disciplinary culture of science. Social norms could promote students' increasing use of inscriptions and determine what types of inscriptions are meaningfully to be constructed, but the criteria generated by the learning community and used to determine the accuracy of inscriptions might not be those used by scientists. Therefore, as this social practice perspective regards a group of students as a local knowledge-building community, significant differences between a local learning community and a professional community of scientists should be acknowledged.

The first difference is between the nature of tasks (and activities) conducted in a science classroom and the ones in a science laboratory. Students at the secondary school level are unlikely to conduct the investigations and demonstrate those sophisticated practices documented in science studies (e.g., Knorr-Cetina, 1983; Lynch & Woolgar, 1990). Therefore, researchers in science education need to take this difference into consideration and explore a variety of inscriptional practices that are developmentally appropriate to middle and high school students.

Secondly, based on expert and novice studies (e.g., Chi, Feltovich, & Glaser, 1981; Kozma & Russell, 1997), scientists and students demonstrate different ways of using strategies, solving problems, and applying knowledge due to their different levels of understandings of scientific concepts and processes. Students are not able to, for example, transform one inscription into another as fluently as scientists (Chi et al., 1981; Kozma & Russell, 1997). Students need more resources and preparations to support their enactment of inscriptional practices (Kozma, 2000a). Thus, educational research that investigates what resources students need in order to engage in inscriptional practices will advance the understandings of how to help students learn inscriptions.

Finally, the norms developed by a learning community in educational settings could match as well as clash with those in the community of professional scientists. Inscriptions, for example, generated and recognized by a learning community might be not accepted by the disciplines of science. This, in turn, could be a barrier for students to enter into the community of scientists. Hence, the cultural negotiation process (Bruner, 1990) between a local group and the community of scientists should be seriously considered when a class is regarded as a cultural community. Knowledge and practices generated within the disciplines of science do not directly enter into a middle school science classroom. They are interpreted and brought into a classroom

by social mediators, such as teachers, curriculum designers, and science educators, who initiate and socialize students to the norms and expectations of the scientific community and help students develop science literacy (Kelly et al., 1998). At the classroom level, therefore, a teacher plays a critical role in constructing a learning community that allows students to experience "what scientists do" based on her understandings of the disciplines of science. The question facing teachers and educators then becomes: "how, in what ways, under what conditions, and with what outcomes will *students* and *scientific knowledge* and *practices* come together?" (original emphasis, Kelly & Green, p. 156). We asked a similar question: How, in what ways, under what conditions, and with what outcomes do students use inscriptions in a science classroom and engage in inscriptional practices that approximate what scientists do? To answer the question, we examined what inscriptional practice students engaged in and how the features of a learning environment (including teachers' instruction and scaffolding) supported them.

Methods

To reveal students' learning processes and the ongoing nature of practices, the methods we employed draw from a naturalistic approach (Lincoln & Guba, 1985; Moschkovich & Brenner, 2000). This approach has been taken by other studies to examine how students or scientists use inscriptions in real-life settings (e.g., Barab, Hay, Barnett, & Squire, 2001; Kozma et al., 2000). Drawing on a naturalistic approach, this study used the following strategies to conduct the qualitative research. First, instead of conducting the study in a laboratory context, we investigated cognitive activities in a classroom context where different features of the learning environment (e.g., student investigations, learning technologies, and teacher scaffoldings) were integrated and interdependent components. Next, to have multiple views of an event, we gathered different types of data to investigate the research questions and allow a

consensus of an event to emerge from a repeated review of data. Finally, we realize that a learning environment involves various factors influencing students' learning, so we considered interactions of multiple variables in the classroom (e.g., practices, inscriptions and teacher's teaching experiences) and did not attribute the learning effects to certain variables in the classroom (A. L. Brown, 1992; Collins, 1999).

Context

The school and the program. The two seventh grade science classrooms participating in this study were taught by two teachers at an independent school in a Midwest university city. This school was a sixth to twelfth grade school with a student enrollment of approximate 75 students per grade. It was not a school for gifted students but did have an admission process that generally included accepting students from the upper two-thirds of standardized test norms.

This school was chosen as a research site because there existed a relationship between the teachers and university researchers. Additionally, based on our previous research experience with them, we expected to see a range of inscriptions used in the site. The teachers had been working with university researchers to develop and implement interdisciplinary, integrated, project-based science curricula (Novak & Gleason, 2000). The goal of the program was to promote students to develop in-depth and integrated understandings of fundamental science concepts and process skills within a context of inquiry. During a school year, several science units were explored that incorporated fundamental science concepts across several science disciplines. Each unit began with a driving question (Marx, Blumenfeld, Krajcik, & Soloway, 1997) that provided students with a real life context. Students collaboratively worked with their group members and conducted a long-term investigation of the driving question and its related sub-questions. Teachers provided substantial supports as students engaged in inquiry through

activities such as asking questions, collecting data, analyzing data, presenting ideas, and generating conclusions (Krajcik et al., 1998). This instructional approach is consistent with the National Science Education Standards (National Research Council, 1996).

The unit. The Water Quality unit, which is the focus of this study, was explored during the school year of 2000-2001. Students experienced three rounds of data collection throughout the unit in order to investigate the change of water quality over a year. We refer to these three sub-units as Water Quality I (WQ I in the fall season), Water Quality II (WQ II in the winter season), and Water Quality III (WQ III in the spring season). The unit began with a driving question about the health of the stream behind the school. The teachers used mini-lectures, class discussions, experiments, and group activities to introduce key ideas in science, including fundamental concepts, the process of inquiry, collaboration, and the use of various technological tools (i.e., portable technology, computers, digital cameras, and a computer-based modeling tool). During each sub-unit (i.e., WQ I, II, and III), students went to the stream behind the school to conduct water quality tests (e.g., pH, conductivity, turbidity, dissolved oxygen, and temperature change). They then analyzed the data, reported their analyses, generated conclusions to answer their driving question, and created artifacts (e.g., science reports, webpages, and computer-based models) to represent their understandings.

Students. Twenty-seven seventh graders participated in this study (N=27, 16 girls, 11 boys) and were taught by two teachers (Class I: 12 students, 8 girls; Class II: 15 students, 7 boys). The water quality unit was the first time that most of the students were exposed to the inquiry-based instructional approach. They were not familiar with the features of this integrated curriculum, including an emphasis on asking questions, long-term investigation, collaboration,

and the use of technological tools. Among the participants, twenty-five of the students were Caucasians and two were Asian Americans.

In each class, two dyads (four students) were nominated by the teachers for intensive observation. These target students were nominated by considering their genders, academic achievement levels, and abilities to verbalize their learning process. According to the school records, all of the target students were identified as Caucasians, although one of them had Asian Indian heritage. The two target dyads in Class I were the same gender groups (one girl group and one boy group) and formed by student self-selection, while the two dyads in Class II were mixed gender and formed by the teacher.

Teachers. Andrea¹ taught Class I. She had ten years of teaching experience, a Bachelor of Science (BS) with a major in broad field science, a minor in biology and health, and a Master of Art (MA) in adolescent development. Celia taught Class II and had 28 years of teaching experiences. She had a BS with a major in biology, a minor in chemistry, and an MA in special education. Both teachers had secondary science teaching credentials. The teachers regularly met before the first class period for planning curriculum, creating materials, sharing handouts and discussing students' progress.

Role of the Researcher

Through the eight months of data collection, the first author attended every class period when the students had activities related to the water quality unit. She knew every student's name and chatted with students during breaks. During the class she was an observer and a researcher conducting the study and did not participate in classroom activities, although she sometimes answered students' questions about the tasks they were supposed to do. When students used the

modeling tool, created webpages, and used other computer software, she was a helper and interacted with them for their content questions and tool problems.

Data Collection

Multiple sources of data were collected during the water quality unit. Every class period in the unit was videotaped and fieldnotes were taken to capture classroom activities. The classroom video recordings illustrated how the teachers supported students to demonstrate their inscriptional practices and provided data of what inscriptional practices students had during the class. Students' artifacts including science reports and notebooks were copied and collected. These artifacts presented various inscriptions created and used by students. Teachers' feedback on the artifacts indicated how certain ways to represent data and reported analyses were valued and emphasized by the teachers. To assess students' competencies to construct and interpret inscriptions, target students were interviewed individually. They were presented a scenario and water quality data and asked to organize and analyze these data. The teachers were also interviewed to understand the rationale behind the curriculum design and their perceptions about the use of scientific inscriptions in the unit. The interviews were transcribed and later analyzed.

Data Analysis

To answer the research questions, several analytic steps were taken (Erickson, 1986). First, we reviewed the fieldnotes, identified episodes on the videotapes that involved inscription activities, and transcribed these episodes verbatim into text files. Episodes were defined as "smaller units of coherent interaction within events" (Jordan & Henderson, 1995, p. 57). The episode transcripts and interview transcripts were then imported into a database for coding.

Second, using the constant comparative method (Glaser & Strauss, 1963), we coded the transcripts using a coding scheme that included types of inscriptions (e.g., data tables, graphs,

models, and webpages), inscriptional practices (i.e., constructing, interpreting, reasoning, presenting, and critiquing), modes of class activities (e.g., recitation, class discussion, and group discussion), teachers' scaffolds, and areas of science inquiry (Krajcik et al., 1998). We define scaffold as assistance that allowed students to accomplish tasks they could not do alone (Palinscar & Brown, 1984; Wood, Burner, & Ross, 1976). These scaffolds allowed students "to participate at ever-increasing levels of competence" (Palinscar & Brown, 1984, p. 122). The definitions and examples of inscriptional practices are shown in Table 1.² To portray how students' interpreting and constructing practices with data tables and graphs changed over time, we identified four codes (i.e., constructing, interpreting, data table, and graph) as "tracers" (Barab, Hay, & Yamagata-Lynch, 2001; Newman, Griffin, & Cole, 1989) that could be observed and followed throughout the unit and across different data sources. Once these transcripts were coded, we extracted those that involved an inscriptional practice and a specific inscription from the files and created reports, such as a report of all episodes about constructing data tables.

Third, we read through these reports and identified coding categories for the second level of coding. These categories included tools or resources used to support practices, criteria indicated by the class members about the quality of practices or inscriptions, functions or characteristics of an inscription created by the class members, structures, formats or components of an inscription, and teachers' scaffolds that support students' enactment of practices. We then reviewed the reports, abstracted information around these categories, and generated descriptions and analytical notes.

Fourth, combining students' artifacts, we reviewed the descriptions and analytical notes to generate temporary themes. Themes were recurrent activities that emerged from the descriptions and notes. We searched for confirming and disconfirming evidence that included

quotes from interview transcripts and descriptions from fieldnotes (Erickson, 1986). We then created rich narratives of these temporary themes that included evidence and analytical notes. The rich narratives enabled us to trace students' learning trajectories and identify general themes across different types of inscriptional practices.

Finally, we reorganized and combined the temporary themes, and reported the general ones. For each general theme, we used confirming evidence from different sources of data to triangulate our interpretations and to increase the credibility.

Trustworthiness Features

To ensure the quality of the research, we used a set of standards and strategies suggested by Mosckovich and Brenner (2000). To achieve the credibility,³ we observed the two classes for more than eight months to avoid distortions that could occur due to unusual events, and collected multiple sources of data to triangulate our interpretations of a phenomenon. We also created a three-page summary of the general themes and shared it with the teachers. We posed questions to teachers in order to confirm our interpretations about the curriculum design and the purposes of having some inscriptional activities. To establish the transferability of the study and help readers to decide its applicability, we selected the research site and target students purposely and provide detailed descriptions of settings, data collection and data analyses. The coding schemes, coded transcripts and episode descriptions were examined by both researchers to ensure the dependability of analyses. Furthermore, all qualitative data were collected by using audio or video devices that allow us to re-examine our descriptions of class events. Lastly, we described the researcher's activities in the research site and provided a detailed account of the research process to achieve the confirmability of the study.

Findings

This section begins with an overview of students' enactment of constructing and interpreting practices in the water quality unit and follows with evidence and detailed descriptions to show students' inscriptional practices when they constructed and interpreted data tables.

Overview of the Enactment of Constructing and Interpreting Practices

Throughout the unit, ten types of inscriptions (i.e., data tables, graphs, chemical representations, tables, pH scale, maps, models, digital pictures, stream drawings, and webpages) were used in the two classes. Among the various inscriptions used, data tables and graphs were most practiced ones in the unit. Table 2 shows the numbers of class periods in which students demonstrated constructing or interpreting practices with various inscriptions. Although the duration of practices within each class period varied, the number of class periods gives a sense about when and how often a practice happened in the three sub-units (i.e., WQ I in the fall, WQ II in the winter, and WQ III in the spring).

Constructing practices were demonstrated in various inquiry areas. Students constructed inscriptions while making predictions, designing investigations, presenting findings, analyzing data and carrying out investigations. During WQ I, students learned to design and create several types of data tables for their pH and conductivity experiments, and then constructed data tables, stream drawings, digital pictures, graphs, and models for their fall water quality investigation. The classes spent a substantial amount of time designing, drawing, and modifying data tables and bar graphs. They discussed qualitative or quantitative data that should be included in data tables (Figure 1), discussed conventions or rules used for a bar graph (e.g., x and y axes in Figure 2), and decided the categories or structures of a table or a graph. These practices were scaffolded by

the teachers during WQ I. In WQ II, students did not explore new inscriptions and had another iteration of creating data tables, digital pictures, graphs, and models for their winter water quality investigation. Having prior experiences in creating these inscriptions from WQ I, the two classes spent relatively less time on these inscriptions. As students had more and more responsibilities to create data tables and graphs, their participation increased and teachers' scaffolds faded out. New inscriptions, i.e., longitudinal graphs (Figure 3) and webpages, were introduced in WQ III, so more class periods involved constructing practices (Table 2).

Most interpreting practices were demonstrated when students analyzed data and presented findings. Students' interpreting practices with data tables and graphs included examining the consistency of data represented by inscriptions, identifying patterns, searching for reasons to explain data, and comparing data to standards, predictions, and conceptual definitions. During WQ I, students learned to interpret various inscriptions, including chemical representations, data tables, graphs, maps, models, and stream drawings (Table 2). Data tables allowed students to examine the consistency of the data and by coloring the background of a bar graph (Figure 2), students could easily compare their data to water quality standards (i.e., excellent, good, fair and poor). In WQ II, students spent relatively less time interpreting these inscriptions because in WQ I students engaged in analyzing data during class time while in WQ II data analysis was assigned as homework which was not recorded by the classroom videos. WQ III focused on the construction of webpages and longitudinal graphs, so there were only two class periods involving students' interpreting practices in which students interpreted their longitudinal graphs.

The overview shows the seventh graders participating in this study spent a considerable amount of time constructing and interpreting data tables and graphs. What were the

characteristics of their inscriptional practices? How did their inscriptional practices change over time? Below we use a series of segments to demonstrate how the classes planned, designed, and constructed data tables and graphs. We then present students' interpreting practices with data tables and graphs, and illustrate how their practices evolved over time. Finally, we discuss four salient features of the learning environment that promoted the development of inscriptional practices throughout the unit.

Constructing Practices with Data Tables and Graphs

Throughout the unit, each student constructed data tables for their pH and conductivity experiments and for their water quality investigation in the three seasons. The classes co-constructed class data tables to share their experimental data and water quality data. They also graphed the averages of their water quality data and combined the data from the three seasons to create longitudinal graphs. At the beginning of the unit, constructing practices associated with data tables and graphs were an important and salient part of classroom activities. As students created and utilized these inscriptions in an iterative matter throughout the unit, the construction of these inscriptions was embedded in students' inquiry processes. Additionally, students' constructing practices evolved over time. The focus of their practices was shifted from the format of a data table to the content of a table.

Designing a data table for the pH experiment (WQ I). In WQ I, teachers supporting students in designing tables seemed crucial for the seventh graders to successfully construct an inscription. As novices at conducting science inquiry, these seventh graders had no experience in creating inscriptions to serve given purposes. The segment shown below is taken from Class I that demonstrates how students constructed their first data table for the pH experiment. In the segment, when the teacher asked students where they could record the data collected from their

pH experiment (Lines 4-6), students' responses (Lines 7-13) suggested that they had limited experience in creating tables.

Segment 1: Designing a data table for the pH experiment

- 1 (CV005A, EP 2) Procedures of the pH experiment are written on the board after
- 2 class discussions. Andrea (T) wants students to think about what should be used
- 3 to record their data.
- 4 T: We wanna test and we wanna record. We know what we're gonna do the test
- 5 now, and this [record] is what we wanna work with. We're going to record the
- 6 data. What are we going to record in? [T circles the procedures, test and record.]
- 7 Carla: graphic notebook.
- 8 T: oh, that's where we're going to record.
- 9 Carla: oh.
- 10 T: in what will we record it in our graphic notebook?
- 11 Charles: number.
- 12 Noah: pencil.
- 13 Student: quantitative.
- 14 T: it's quantitative data with our emate. We could also include qualitative data,
- 15 right?
- 16 Cynthia: we're gonna have to make a...uh like a table of it.
- 17 T: we need to create some kind of table.
- 18 Cynthia: can we do that in computer?
- 19 T: we can. You can. A data table. We need somehow to create a data table.
- 20 Why do we wanna do that? Annie.
- 21 Annie: because ... organize?
- 22 T: yes, we wanna organize our results. We wanna organize them. [T points to the
- 23 procedure on the board.]
- 24 T: okay. This is what I want you to do. With the person next to you, I want you
- 25 somewhere in your graphic notebook to create a data table. Think about
- 26 everything that has to go in there. Take all the stuff. See what you come up with.
- 27 I'm not gonna give you a data table. We're gonna create one together.

In response to students' answers, Andrea rephrased her question (Line 10), but it seemed that students still did not fully understand the question or had no idea about using tables to record data. Although Cynthia suggested using a table, she seemed not certain about it (Line 15). Andrea confirmed Cynthia's answer and further asked for the purpose of using a data table (Lines 19-23). Annie gave an appropriate response, but she was also not confident about her answer (Line 21). When Andrea assigned the task, she indicated where students should draw the

table, but did not provide specific information about the format or the possible content of the table (Lines 24-27). As can be seen in the next segment, some students did not know what a data table was supposed to look like (Lines 28-32). Based on students' constructing practices demonstrated in groups, Andrea provided more information about what should be included in their table (Lines 36-39).

Segment 2: Designing a data table for the pH experiment

- 28 (CV005A, EP 2) Students work in groups to design their pH table. T is at a table
 29 with four girls. One girl's (Carla) idea is to use a pH scale and indicate different
 30 substances on the scale. T indicates that she could do that afterward, so she can
 31 show the pH values and substances on the line. Carla then draws something on
 32 her notebook and shows it to T.
 33 T: Carla, I think that's a great idea after we get the data. That's one way,
 34 remember we said graphing, somehow we need to represent our data. That will
 35 be one excellent suggestion. Okay. But first we need to collect our data. We
 36 need to have spaces to put... We [T raises her voice and talks to the class] need to
 37 have spaces to put 3 times, right?
 38 Students: yeah.
 39 T: and the averages. Come up with some kinds of table, talk with each other.

At the end of the first segment, Andrea did not explain what a data table was supposed to look like. Rather, she used the group discussion as an opportunity to explore students' prior understandings about the construction of data tables. When Andrea realized students' difficulty through Carla's question (Lines 29-32), she provided more specific instruction to support students' constructing practices. Her suggestion about having space for three trials and averages became important (Lines 36-39) for students to successfully create an appropriate data table for their experiment. Students' final pH tables show that they took up the teachers' suggestion. Four groups presented their data tables and all of them were quite similar that contained columns for predictions, three trials, and the average. Cynthia's table in Figure 1 is an example.

These two segments about designing a data table for the pH experiment show that students' initial constructing practices were guided by the teacher and the teacher's scaffolding was crucial for these novice inscription constructors to engage in planning and constructing practices. In addition, engaging in constructing practices required students to think about in what situation data tables could be used, what a data table should look like, and what experimental procedures should be considered in order to construct useful tables. That is, students' understanding about the experiment and the inscription could interact with constructing practices. Below we use two other segments to elaborate on this point.

Creating a data table for water quality investigation (WQ I). After students created their pH data table, they also constructed two data tables: one for the conductivity experiment, and a second, more complicated data table for their water quality investigation. This complicated data table had to include data from five water quality tests and each test had three trials from three locations. In the following segment, Andrea and students in Class I designed their data table together during WQ I. Having created three data tables for their experiments, students were able to decide what data and categories should be included in their table (Lines 5-21). Andrea reduced the complexity of creating a data table by using a series of questions to scaffold students' constructing practices. Notice that understandings about the procedures of their water quality investigation were required to design an appropriate data table. That is, the context of inquiry should be considered when designing an inscription.

Segment 3: Creating a data table for the water quality investigation

- 1 (CV039A, EP 1)
- 2 T: The first thing we wanna do is to design a data table. To go outside to collect
- 3 data that we can put in for all 5 of the chemical tests.
- 4 T: okay, what are the tests that we have first of all? What's one?
- 5 Charles: pH.
- 6 T: pH. And others?

- 7 T records students' ideas on the board.
- 8 Noah: temperature.
- 9 T: temperature.
- 10 Smita: dissolved oxygen
- 11 T: dissolved oxygen
- 12 Smita: conductivity.
- 13 T: what's the last?
- 14 Noah & Smita: turbidity.
- 15 T: turbidity. okay.
- 16 T makes a list of 5 tests on the board.
- 17 T: what we need to do is create a data table that's going to include all these 5
- 18 tests. Is going to include...what else?
- 19 Students have no response for seconds.
- 20 T: so we need to set up the 5 tests.
- 21 Austin: oh, three locations.
- 22 T: yes, three locations. So we have 5 tests, we have A, B and C for locations
- 23 [writing the information on the board]. And what else do we need?
- 24 Smita: we should do each times three.
- 25 T: and we need to do each times three. [Writing on the board] Three locations,
- 26 three trials, and what else?
- 27 Charles: the averages.
- 28 T: the averages.
- 29 Smita: three trials per location.
- 30 T: three trials per location, so three for A, three for B, and three for C.
- 31 Charles: three trials per location, per test.
- 32 T: per test, plus average for each location per test. So you need to design a data
- 33 table. That's gonna accommodate all the stuff that we need to include.

In this segment, the class did not need the teacher's scaffolding about the format of a data table. Their practices focused on the content and the categories of a table. The teacher's questions played an important role in directing students' attention to the five water quality tests and supporting students to design a complex data table. When students constructed their first data table for the pH experiment, the teacher suggested the categories of the table. As their experiences in designing increased, students volunteered their ideas about what should be included in their table, which included five tests (Lines 5-15), three locations (Line 21), three trials for each location (Line 24) and the averages (Line 27). These ideas were relevant to the procedures of their investigation and meaningful in the context of their inquiry.

Because not all test data were quantitative and collected by probes, in the following segment, Andrea reminded them to consider the different types of data collected from the five tests (Lines 36-38). When students began thinking about how to modify their table in order to accommodate different types of data, their confusion and questions about the investigation were revealed (Lines 39-44). The teacher used it as an opportunity to review procedures of the turbidity test (Lines 45-48).

Segment 4: Accommodating different types of data in a table

- 36 T: okay, let's me help you out a little bit though. You realize that these ones [pH,
37 temperature, conductivity, D.O.] we're gonna actual numbers, right? And this
38 [turbidity] we won't.
39 Charles: we don't need three times for that, right?
40 T: uh...
41 Charles: could you just take a look at it and write down, take a look at it and write
42 down?
43 T: how did we already agree that we're gonna collect this data?
44 Charles: the coffee filter.
45 T: yeah, we're gonna sample from each location and we'll strain that through
46 coffee filter, so that is gonna be a little different. So maybe instead of having
47 three boxes for A, B, and C, we'll just have one bigger box and you can put things
48 like that [draw a box with particles on the board] if you want.
49 T: save a space to write. Beth?
50 Beth: do we need to have predictions?
51 T: that's an excellent question. In all of the tests we done so far, we have had
52 predictions that's part of the data table. This time we're going to make
53 predictions separately. That's one thing we're going to do on Monday. Thank
54 you very much. So on our data table here, we won't have a spot for predictions.

Andrea's scaffolding about the turbidity data (Lines 36-37) led to Charles's question. The brief discussion between Andrea and Charles (Lines 38-46) indicates that Charles was not prepared for recording different types of data into his table. Andrea's follow-up scaffold (Lines 43-46) clarified Charles's confusion and pointed out close relationships among content knowledge (turbidity test), investigation procedures (using coffee filters), data types (drawings of filters), and inscriptions (having bigger boxes in the data table). In addition, in their previous

data tables, students had a column for prediction (see Cynthia's pH data table in Figure 1).

Beth's question (Line 48) shows that she had internalized the idea of having predictions in a data table. Andrea's response to Beth's question (Lines 49-52) signaled that the question was legitimate and meaningful in the context of designing a new data table. Later Andrea showed them what a prediction paragraph looked like, so students would write up their predictions for the five tests in text instead of recording them in their tables.

These two segments indicate that constructing tables provided students with opportunities to discuss, review, and clarify questions about the investigation they were going to conduct, and that the data table became a learning tool for students to organize and plan their investigation. As students had more experiences in creating data tables, they were more actively participating in designing a new inscription. Additionally, the whole class discussion focused on covering all necessary categories in their tables without going through some essential questions such as why they should use a table and what a data table should look like. The class appeared to develop and internalize a common understanding about what a data table is and what it is used for. The common understanding that the class had developed allowed the teacher to assign the construction of data table as homework during WQ II and WQ III. In the last two sub-units, the teachers' scaffold in constructing data tables faded out. The classes did not go through the construction process again and the teachers just reminded them to use the data table they had in WQ I as the template.

Data tables were used across three sub-units. The series of segments shown previously portray the learning trajectory of students' constructing practices with data tables. If students were able to fully participate in constructing data tables without the teacher's scaffolding at the

end of the unit, what did students' constructing practices look like if they had an opportunity to create new inscriptions in WQ III?

Co-constructing a longitudinal graph (WQ III). In WQ III, students drew on their prior experience in constructing bar graphs (Figure 2) and actively participated in designing a new inscription such as longitudinal graphs and webpages. To illustrate students' constructing practices in WQ III, we use a segment to show how class members co-constructed a longitudinal graph.

In a longitudinal graph, students were supposed to represent their data across the three seasons. The difficulty and complexity of the inscription increased. In the segment below, Andrea first defined what a longitudinal graph was (Lines 4-6). Based on the definition, the class discussed what longitudinal data they had and how they should construct a longitudinal graph. Notice that the class demonstrated a very different discursive pattern compared to those shown in their discussions during WQ I. Although a longitudinal graph was new to them, students not only provided ideas about what data should be included as they did during WQ I, but they also had suggestions and comments on the format and structure of the graph.

Segment 5: Co-constructing a longitudinal graph

- 1 (CV106A, EP 3) T writes down "Graphing—Longitudinal data" on the board, and
- 2 asks the class if anyone knows what "longitudinal" means. Charles makes a guess
- 3 about "long" in the word. T then explained that longitudinal data is data taken
- 4 from a study that occurs for a long period of time.
- 5 T: We've been doing a longitudinal study this year. What's our long period of
- 6 time?
- 7 Charles: the water quality of the stream in three different seasons.
- 8 T: three different seasons. Okay. So what we're gonna do this time, instead of
- 9 just graphing the averages of the three locations. We're gonna graph over the
- 10 whole year. [T sketches x and y axes on the board without units and numbers.]
- 11 T: so let's say this is umh...you can title it, year long pH data. [Title the graph on
- 12 the board (see Figure 3)] okay. What do you think we could do? Sally.
- 13 Sally: month one and two.
- 14 T: we could do month one, month two, month three. What else could we do?

- 15 Stefon: fall, winter and spring.
 16 T: fall, winter and spring.
 17 Charles: A, B and C.
 18 T: A, B, and C [on the x axis], we might get messed up with our old graphs.
 19 Charles: each A, B, and C under like, maybe spring.
 20 Carla: can we do the graphs like we did? Different colors, it's a bar graph, but
 21 has different colors.
 22 T: yes.
 23 Carla: we can do that thing.
 24 T: We're gonna combine all those ideas. Fall, winter and spring [label the x axis],
 25 pH...
 26 Cynthia: can we do it on separated graphs?
 27 T: no, instead of just doing separated graphs, then doing longitudinal, we put our
 28 spring data on a longitudinal graph. So what kind of bar graphs can we have
 29 here?
 30 Cynthia: we can have like three colors, we have for fall, winter, and spring. For
 31 like fall we have...
 32 T: Annie, do you have any idea?
 33 Annie: we can have different bars for fall, the seasons.
 34 T: so we'll have a triple bar graph whenever we had, right? And this will be A, B,
 35 C, A, B, C, A, B, C. If you get this, and you say oh, I can go home and do that on
 36 my computer. Do that for homework for one of your tests. If you don't get this...
 37 Carla: is this overall?
 38 T: this will be over the whole year, fall, winter and spring.

Although students had never constructed a longitudinal graph, they drew on their experience of constructing bar graphs (Lines 15, 17, 20-21). Carla (Line 20) and Cynthia (Lines 26, 30-31) had comments on what they thought would be a better graph to show seasonal data based on their experience in creating graphs. Compared with the discussions the class had when designing the pH data table, this segment shows a very different discursive pattern. There were more back and forth dialogues between students and Andrea. Andrea's responses and guiding questions were shorter than those in previous class discussions. Annie provided a specific suggestion about the format of the graph (Line 33) that was taken up by Andrea (Figure 3). This shows that at the end of the water quality unit, students were capable of fully participating in designing a more complicated inscription. Even though Andrea had the authority to decide what

comments or ideas should be used for their longitudinal graph, students had confidence in expressing their ideas and deciding the content and format of the inscription. More importantly, most of their ideas were appropriate, important and meaningful for designing an inscription to serve a given purpose. The graph sketched by Andrea on the board (Figure 3) shows that students' ideas were taken into consideration.

Together the series of segments illustrate that students' constructing practices with data tables (Segments 1 through 4) and graphs (Segment 5) evolved throughout the unit and interact with their understandings about inscriptions, content understandings, and the inquiry process (Barab, Hay, Barnett, & Squire, 2001). These interactions were also observed when students interpreted inscriptions that will be described below. As students created and utilized these inscriptions in an iterative matter throughout the unit, the construction of these inscriptions became an integral part of the inquiry process.

Interpreting Practices with Data Tables and Graphs

In the water quality unit, students analyzed data collected from the pH and conductivity experiments and from their water quality investigations across the three seasons, and wrote up their analyses in their science reports. Interpreting the data tables and graphs (including bar graphs and longitudinal graphs) was an important part of data analysis. Below we present a series of segments to demonstrate students' interpreting practices with data tables and graphs.

Using data tables to examine the consistency of data. During WQ I, after students conducted pH and conductivity experiments and recorded data in the data table, the teachers created a class table on the board that allowed students to share data and compare data across groups. As Celia said during the interview, "in a data table you're...when you go to analyze numbers, it's helpful to have everything that's the same in one category so right now it makes it

easier for comparison.” That is, data tables organized data in a way that helped students compare data across groups and make sense of the data.

Although scientists usually use graphs to identify outliers (Smith, Best, Stubbs, Johnston, & Archibald, 2000), the seventh graders in this study always used data tables to identify outliers because these students dealt with relatively simple sets of data. The following segment shows an example. Throughout the class discussion, Celia referred to the class data table (Figure 4) several times (Lines 3, 15, 17, 22) and directed students’ attention to outliers and data across groups. Guided by Celia’s questions Class II engaged in interpreting practices including identifying outliers and examining the consistency of data.

Segment 6: Interpreting a class data table

- 1 (CV013C) Celia (T) creates a data table on the board and records the data students
- 2 collected from their pH experiment.
- 3 T: all right. Let’s take a look at these data. The numbers actually are pretty
- 4 consistent. There’re few outliers. What do we consider data that’s an outlier that
- 5 doesn’t fit them all?
- 6 Several students raise their hands.
- 7 T: Nathan.
- 8 Nathan: like an example?
- 9 T: yeah.
- 10 Nathan: if we had 10.2 and 10.3, the outlier would be like 14 or something.
- 11 T: so far. The averages are pretty much the same. Do we see any outlier in this
- 12 data? Olisa?
- 13 Olisa: I think maybe in the salt column. We had 5.0 and someone else had 7.91,
- 14 so there is a difference between them. I think 5.0 may be the outlier.
- 15 T: how about in the peat moss group?
- 16 Alan: yeah.
- 17 T: that’s certainly an outlier. [Circle the numbers which are considered as outliers
- 18 (see Figure 4).]
- 19 T: okay, sand, tide. Is there any other extreme outlier here that we could say?
- 20 Elaine?
- 21 Elaine: I guess acid rain, the 1.72, ‘cause most of them are higher.
- 22 T: yeah, that might be kinda lower. This whole column here [student group 6] is
- 23 reading on the low range, except here and salt. They’re probably the closest to
- 24 what should be.

In this segment, students in Class II took a close look at numbers shown in the same row (Figure 4), compared the numbers, and identified the numbers that they thought were out of a normal range. Celia posted a series of questions (Lines 4-5, 11-12, 15, 19) to guide the discussion. Without these questions, the students, as novice science investigators, might have not known what they should do in order to determine whether their data were in a range of "what should be" (Line 24). Celia's questions directed students' attention to certain aspects of the data represented in the data table and sequenced the process of interpretation. The first thing to do was to take a close look at the data and identify outliers (Lines 3-14). Several outliers were found in different substance columns (Lines 15-21). The data table (see Figure 4) not only allowed the class to examine the consistency of data by comparing data of the same substances, but it could also help them see whether data collected from a specific group tended to be higher or lower (Lines 22-24). After this segment, the class discussed possible causes of these outliers and engaged in another type of interpreting practice: searching for reasons to explain data. Students volunteered their ideas about why there were outliers. This discussion expanded on their discussions about the causes of the outliers and analyzed what kind of human or technical error might cause a certain type of outliers.

What did students interpret in Segment 6? The pH data or the data table? Although data tables used by the students did not show visual patterns as graphs do, students used data tables to represent and reorganize the raw data in a way that allowed them to easily visualize and compare data collected from different groups. This in turn helped them examine the consistency of data. Therefore, students did not interpret the raw data but the data represented by a data table. If the data table had a different format or had different categories, students might have come up with different findings about the data. In this sense, how an inscription represents and transforms data

allows as well as constrains students to generate certain meanings out of the inscription and to demonstrate certain inscriptional practices.

Teacher's modeling of interpreting practices (WQ I). In Segment 6, Celia guided students to focus on certain aspects of data in order to generate meanings of the class data table. This again shows that the teacher's scaffolding was important for these seventh graders to demonstrate competent interpreting practices. After students collected water quality data in WQ I, to help students analyze data by using data tables and graphs, the teachers provided instruction and a guideline sheet. Both teachers used one or two water quality tests as examples to model how students should analyze their water quality data collected from their testing locations. For example, when modeling how to interpret temperature data, Celia indicated that students could report the data and then presented possible reasons that attributed to the temperature differences (CV052C). She also suggested possible reasons to explain their temperature data including people dumping warm water, technical problems, human errors, and decomposition. Celia's instruction in WQ I was very detailed and used a specific test as an example so that students could have a concrete idea about data analysis. During WQ II, she did not provide such detailed instruction but briefly reviewed the guideline sheet. Although the teacher's scaffolds faded out, according to the analysis of group discussions, students were able to draw on different resources to demonstrate interpreting practices as shown in the following segment.

Interpreting data collected from the stream (WQ II). Segment 7 took place in Class II during WQ II and shows that interpreting practices required substantial conceptual knowledge and field experience in the stream. When Nathan and Olisa tried to figure out reasons to explain their data, they drew on resources including background knowledge they learned about the tests,

inscriptions or data collected from previous investigations (Lines 13-22) and observations they made from the stream (Lines 24-25).

Segment 7: Interpreting pH data

- 1 (CV052C, EP 5) Nathan and Olisa calculate the averages and record them in their
- 2 data table. Both of them have their notebook as the discussion is going.
- 3 Nathan: for point A, pH test 1, what did you get? Average or whatever?
- 4 Olisa turns to the table page.
- 5 Olisa: for point A, you mean like trials or overall average.
- 6 Nathan: overall average.
- 7 Olisa: 7.22
- 8 Nathan: okay.
- 9 Olisa: for point B, 7.15.
- 10 Nathan: uh.
- 11 Olisa: for C, 7.20.
- 12 Nathan: okay.
- 13 Olisa: so fertilizer, is fertilizer basic?
- 14 Olisa turns to her pH lab data table (See an example in Figure 1).
- 15 Olisa: so fertilizer, wait, fertilizer is acidic.
- 16 Nathan: are there different kinds though?
- 17 Olisa: yeah, that's true.
- 18 Nathan: they're probably most acidic.
- 19 Olisa: yeah, 'cause it's [fertilizer] like 5.61 (Looking at her pH data table).
- 20 Nathan: yeah.
- 21 Olisa: the average for fertilizer. So fertilizer won't affect it. So is...soap is basic.
- 22 Nathan: what kind of soap?
- 23 Olisa: Dawn and Tide.
- 24 Nathan: yeah, that was basic.
- 25 Olisa: and sand, a lot sand will get in because of the sand bar. Point B is where
- 26 the sand bar is, is kinda close to neutral, so I don't know, maybe just a little bit.

This segment happened at the end of WQ II. Olisa and Nathan searched for causes of their pH test results. Olisa first suspected that fertilizer might cause the slightly basic pH (Line 12), but her pH experiment result showed that fertilizer was acidic (Lines 13-17). (A pH reading of 7.20 indeed could be viewed as neutral. Several students in both classes including Olisa regarded neutral as a point on the pH scale instead of a range.) By checking her pH data table, she found out that other substances such as soap and sand might get into the stream and cause the

stream to be basic (Lines 20-24). Olisa then brought up her observations about the location and tried to justify her argument about sand getting into the stream (Lines 24-25). This segment suggests that during WQ II students were able to demonstrate interpreting practices without teacher's prompts. Additionally, the data table created in the pH experiment and students' observations of the stream became a resource for them to demonstrate interpreting practices. Yet, this segment also reveals that students' understanding about pH level was partially accurate and that they did not consider the possible errors made by the instrument.

Interpreting longitudinal graphs (WQ III). As longitudinal graphs were introduced in WQ III, students not only adjusted their constructing practices but also interpreting practices to participate in the activities associated with this type of inscriptions. Longitudinal graphs (Class I using bar graphs [Figure 3] while Class II using line graphs [Figure 5]) showed data across three seasons and allowed students to demonstrate interpreting practices such as identifying patterns or trends of data. The classes defined identifying patterns as searching for similarities and revealing differences among data readings. Based on the similarities and differences they identified, students then discussed factors or causes that might affect the test results. So identifying patterns was an important step for students to make sense of data and helped them go beyond simply reporting or describing data.

Similar to how they did when designing this new type of inscription, students drew on their prior experience in interpreting and analyzing data to generate meanings out of their longitudinal graphs, even though they did not use longitudinal graphs before. The following segment shows students' initial attempt to identify patterns by viewing their longitudinal graphs together. Abby and Mason first described what they saw from these graphs (Lines 4-12). They tried to see patterns of seasonal changes across five tests. However, in some tests the spring data

were the highest, but in some tests the fall data were the highest. After checking the guideline sheet (Lines 16-20), Abby focused on one test and discussed what might be reasons that caused the seasonal change of conductivity (Lines 21-24).

Segment 8: Interpreting longitudinal graphs

- 1 (CV113C) Mason and Abby in Class II lay out all their longitudinal graphs on the
- 2 floor. They are trying to find a pattern from their longitudinal graphs. They look
- 3 at the graphs and describe how the lines go up and down.
- 4 Abby: spring is always going straight across except for DO and temperature. This
- 5 is like no pattern. No pattern.
- 6 Mason: it goes every time you test it, it goes up. See, fall is the lowest.
- 7 Abby: okay. with this.
- 8 Mason: it always goes down.
- 9 Abby: but this one, you can't tell.
- 10 Mason: 'cause there's no pattern.
- 11 Abby: right, there's no pattern.
- 12 Abby: there's no pattern here. [Pointing to another graph]
- 13 Abby: okay, so our patterns for DO and conductivity. What's your pattern, Alan?
- 14 Can I see your patterns?
- 15 Abby: where is that sheet?
- 16 Abby takes a look at the guideline sheet and begins taking notes.
- 17 Abby: there's a pattern in conductivity.
- 18 Mason: conductivity and DO.
- 19 Abby: okay, here [the guideline sheet] says what might explain, changes from
- 20 season to season. 'cause for the conductivity graph, every time...
- 21 Mason: 'cause there's fertilizer.
- 22 Abby: okay, season to season conductivity goes up, fall, winter, spring. Fall is the
- 23 lowest, then winter and spring because in spring there's fertilizer.
- 24 Mason: winter has salt.

Initially Abby and Mason attempted to identify common visual features or trends shown in all their longitudinal graphs, such as the data lines moving up and down. Their attempt was not successful as the tests showed different seasonal changes. In this segment, the guideline sheet (Figure 6) became an important resource that contained questions to structure the pattern-searching process. The sheet asked students to "look at each of the test results" and "see if there are any patterns." It also contained several guiding questions: "Are there changes from season to

season? If yes, what might explain these changes? Do the changes increase or decrease water quality? Why?" According to the sheet, instead of looking for patterns across all tests, students should look at each of the test results and describe changes from season to season. After Abby read the sheet, the pair focused on one test, and their discussion went beyond describing data shown in the graph and involved reasons that might attribute to changes from season to season. When demonstrating these interpreting practices, Abby and Mason drew on their background knowledge about conductivity and their prior experience in interpreting graphs. For example, fertilizers and salts (Lines 21-24) were substances that they tested in their conductivity experiment. Notice that students did not use their notebooks or science reports in order to know when the substances were used in a year and what impact these substances had on the stream. They might have internalized some background knowledge that allowed them to demonstrate interpreting practices.

The previous segments of interpreting practices (Segments 6, 7 and 8) suggest that as students had opportunities to engage in analyzing data in an iterated manner, they were able to participate in interpreting practices and draw on their prior knowledge with less scaffolding from teachers and fewer resources over time. Their participation in interpreting practices indeed increased throughout the unit. Furthermore, their interpreting practices became more sophisticated in WQ III. Below we use Smita's science report to show an example.

Interpreting practices demonstrated in science reports (WQ I & WQ III). Comparisons between students' analysis paragraphs in WQ I and WQ III show that their interpreting practices improved substantially in terms of integrating ideas from different resources and presenting their ideas about why there were seasonal changes. Smita's pH analyses in WQ I and WQ III are a typical example, which are presented below without any editing.

1 Smita's pH analysis in WQ I:

2 Location A

3 At A the pH was near or very close to excellent. The pH was 6.9. There were no
4 acidic or basic substances in the water. For one of the three tests at the spot we
5 even got a pH reading of 7, the perfect reading. The pH should hopefully continue
6 to stay in this range.

7 Location B

8 Because there were no carwahas at this time of year, no acid rain, or any other
9 occurrence that affects pH the reading was excellent. At 7.4 we were very close
10 to perfection.

11 Location C

12 At C the pH reading was, again, very close to excellent. I have formed an idea
13 about the stream. I think that there are so many acidic and basic substance that
14 the water has become neutral. This could be why the reading was 7.2

15 [Teacher's comments: predictions? Like what substances? Explain.]

17 Smita's pH analysis in WQ III:

18 For pH I had first predicated that the pH would be between 6.5-7. Because I saw
19 no reason why it shouldn't be. All through winter I predicated that the pH would
20 be neutral. The pH stayed at an excellent range through most of winter.

21 Numbers, however, continued to rise by a small amount at each season we tested.
22 In the fall the pH at location A was 6.89, Location B had a pH of 7.4 and the pH
23 at location C was equal to 7.2. These numbers are all in the excellent range to
24 determine standards. Having the pH be so neutral was, in some ways, a surprise.

25 An excellent standard for pH most likely means that there are no harmful
26 chemicals in the water. This is because regular distilled water has a pH of 7.

27 Various chemicals such as soap and fertilizer are either higher or lower,
28 depending on whether the chemical is an acid or base. However there are other
29 ways in which a stream's pH can be adversely affected. In the winter the pH rose
30 by the slightest amounts. Although all excellent, a=7.71, b=7.78 and c=7.75, we
31 still saw a small increase. The numbers increased even more in the fall. Location
32 A, B, and C were all equal to 7.9 this standard is good. After considering the
33 other data my partner and I found that the conductivity levels were exceptionally
34 high. Reaching its peak in winter. As we talked about in our background
35 information, conductivity is the amount of dissolved substances in the water.

36 Among these substances is salt which had a pH of 7. In the winter a lot of salt is
37 dumped on the roads. This would make winter data excellent. In the fall people
38 use high bases and acidic substances which, when mixed together, cause a neutral
39 pH. The same goes for spring.

40 [Teacher's comments: good.]

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In WQ I, Smita discussed each location separately in her pH analysis. For readings of location B and C, she presented possible reasons (i.e., no substances or acidic and basic substances mixing together) for the neutral readings (Lines 7-15). In WQ III, Smita's argument was more coherent and she was able to provide a specific example about salt to elaborate her idea (Lines 36-37). Furthermore, she linked her analysis to the background information (Lines 34-36) and used other test results (i.e., conductivity and previous pH experiment) to support her argument (Lines 26-28, 37-39). Although she did not explicitly mention any specific inscription used for her analysis, in terms of creating a science report, she demonstrated sophisticated interpreting practices by connecting her analysis to background information, other test results, and a previous science experiment.

Together the eight segments and Smita's pH analyses suggest that the level of students' participation in constructing and interpreting practices increased over time and demonstrate transitions from peripheral to full participation (Lave & Wenger, 1991). At the end of the water quality unit, students were capable of integrating and drawing on various resources (including their prior knowledge and experience in practices) to participate in constructing a more complicated inscription and interpreting a new inscription. Additionally, during interviews, students voluntarily used data tables and graphs to organize information, present findings, and generate interpretations, and drew conclusions. What aspects of the learning environment helped students to do so? Below we identify features of the curriculum that provide insight into this question.

Design of the Learning Environment

To understand how the learning environment helped students develop inscriptional practices, we identify salient features of the curriculum. Before we discuss these features, we

would like to present the rationale behind the curriculum design provided by one of the teachers who helped design the curriculum.

- 1 We're trying to have students be a part of the process. The goal is for them to
- 2 understand how to design, come up with a good question, how to design an
- 3 experiment and everything that entails that, which means thinking about
- 4 procedures, how to create data tables, how they're going to collect the data. And
- 5 so in the water project in seventh grade, we kind of carefully take them through
- 6 those steps, and you'll see as we get farther along, um, we'll step back a little bit
- 7 and say to the students "Okay, what do we need to do next?" And hopefully
- 8 they'll say, "Okay, well, we need to think how we're going to collect data."
- 9 (Andrea, Teacher's interview #2)

In response to an interview question about why students should create a data table, Andrea stated that the teachers intentionally helped students participate in science inquiry, such as developing a good question, designing an experiment and procedures, creating data tables, and collecting data (Lines 1-4). Additionally, the inquiry process was sequenced and scaffolded (Lines 5-6). Teachers' scaffolding would be gradually faded as students engaged in inquiry in an iterated manner (Lines 6-8). Andrea's statement echoed four salient features of the curriculum that were presented previously: (1) embedding the use of inscriptions in students' science inquiry, (2) providing scaffolds to support students' inquiry process, (3) sequencing tasks and the inquiry process, and (4) engaging students in science inquiry in an iterated manner.

Throughout the unit, the use of inscriptions was not assigned as an isolated task to accomplish; rather, it was embedded in a context of inquiry. Inscriptions were used to plan scientific investigations, record data, analyze data, draw conclusions, and present findings, and inscriptional practices were demonstrated in various inquiry areas. Embedding the use of inscriptions in students' science inquiry signaled that inscriptions were an important and inseparable part of science inquiry and mirrored scientists' use of inscriptions.

Additionally, teachers' scaffolds were crucial to support students' enactment of inscriptional practices. Teachers modeled inscriptional practices, indicated their expectations, posed questions, sequenced the tasks, and suggested that students draw on resources based on students' learning performances. Analyses of the segments presented previously suggest that teachers' scaffolds initiated and mediated many of students' inscriptional practices and encouraged students to increase their participation in these practices.

Furthermore, sequencing and iterating the inquiry process developed continuity of practices that enabled students to develop their inscriptional practices in sophistication and increased their participation in inscriptional activities throughout the unit. For example, to make analyzing data feasible to seventh graders, the teachers structured the process of data analysis into four steps: (1) Reporting results at each testing location; (2) Comparing the results with the standards; (3) Figuring out why; explaining and discussing data by tying in background information with data; and (4) Comparing results with the predictions. These four steps were emphasized by the teachers during class and written in a guiding sheet for students to review. These steps became guidelines when students analyzed data and encouraged them to engage in various interpreting practices, including examining the consistency of data, identifying patterns, figuring out why, and comparing data to standards, predictions, and conceptual definitions. Each of the steps led students to use different inscriptions and engage in different interpreting practices. For instance, data tables were used to describe both raw and calculated data. Longitudinal graphs were particularly useful when students reported the seasonal changes including identifying patterns shown in the graphs (see Segment 8 in interpreting practices). Graphs helped student make a comparison between the results and the standards because standards were colored on the background of the graphs (Figure 2). The inscriptions constructed

in early experiments such as the pH and conductivity data tables became resources and part of students' background knowledge, and facilitated students to make explanations about the data (see Segment 7 in interpreting practices).

During each sub-unit, students went through the same four steps but in a more sophisticated way, so there was continuity of practice developed throughout the unit similar to the findings shown by Tabak (1999). As Andrea told students during WQ II data analysis (CV089A),

What we're trying to do is take experiences that we had in the Fall, with data analysis and writing, you did pretty well. But now go to a next level. That's what we're working on now. It would be a different version of the same idea.

Smita's pH analyses in WQ I and WQ III suggest that although both analyses reported data, compared data to standards, and explaining results, Smita's interpreting practices became more sophisticated by making a coherent argument, providing examples, referring to the background information, and relating pH to other tests.

Additionally, students internalized the four steps and began their data analysis while constructing inscriptions. During WQ II, when Charles and Stefon averaged and graphed the data that they just collected from the stream, Charles commented on their D.O. data, "There's something weird with our DO. It [Location A] went down in waterfall, but it [D.O. in Location A] got worse" (CV087A). Charles noticed that their data did not make sense because according to his observation on the stream, the D.O. in the location down the waterfall was supposed to be higher. He began to interpret data as they created graphs without any prompt from the teacher. In addition, when four target student pairs wrote data analyses for their webpages in WQ III, they did not need the guideline sheet to remind them what should be included in their analyses. They were able to search for resources and include all the information required according to the four

steps. These changes in students' interpreting practices might have not been made if the process of data analysis was not sequenced and iterated.

Discussion

Drawing upon a naturalistic approach, we investigated students' constructing and interpreting practices with data tables and graphs in two seventh grade classes during an eight-month instructional unit. The findings show that seventh graders could demonstrate competent, purposeful inscriptional practices when they were scaffolded by the teachers and the curriculum in a learning environment where the inscriptional activities were sequenced, iterated, and embedded in scientific inquiry. Additionally, through constructing and interpreting data tables and graphs, students could externalize their conceptual understandings, review the inquiry process, share ideas, and make sense of data. Thus, engaging students in inscriptional practices might be beneficial for them to construct understandings about concepts and inquiry. Although without a control group this study is not able to attribute students' development of inscriptional practices to specific factors, by exploring the inscriptional practices that seventh graders were able to demonstrate, this study provides insight into theoretical claims regarding the value of using scientific inscriptions at the middle school level and the impact it has on science learning.

Inscriptional Practices in a Learning Community

The findings suggest that constructing inscriptions could have positive impact on students' understandings about scientific inquiry. For example, when designing data tables, the classes engaged in discussions about experimental procedures and data formats in order to include all required categories. When creating a longitudinal graph, the classes focused on how to represent changes across a year into a visual pattern. As an object of practices, an inscription makes the content of conversations and the entity it inscribes (e.g., a concept or an experimental

procedure) concrete and visible. Students could attach information to an inscription and modify its format and content to reflect upon their emergent understandings. As Penner (2001) argued, "developing scientific understanding can be viewed as the appropriation of tools allowing students to build on their current knowledge while engaged in socially mediated activity" (p. 28). Inscriptions could be such tools. Additionally, creating an inscription via group collaboration and class discussions allowed students to co-construct and negotiate meanings of the inscription and associated inquiry areas. This finding expands theories developed by previous studies with the participation of small groups of college students or scientists in a non-classroom context (Kozma et al., 2000; Lynch & Woolgar, 1990) by showing that middle school students could also use inscriptions to construct collective scientific knowledge in inquiry-based classrooms.

Furthermore, the development of students' interpreting practices suggests a progression in scientific thinking according to the research on science reasoning (Dunbar & Klahr, 1988; Karmiloff-Smith, 1986; Klahr & Dunbar, 1988; Kuhn, 1989). As students became more competent in interpreting and reasoning about inscriptions, they expressed more opinions or comments on the design of interpretations or on the conclusions drawn from inscriptions. They also developed more coherent arguments in their writing about data and inscriptions. Research on science reasoning has indicated that while younger children tend to make inferences consistent with the last results generated and ignore earlier discrepant evidence, older children appear to produce a more coherent narrative and construct a consistent theory by coordinating the succession of instances that they observed (Karmiloff-Smith, 1986; Klahr & Dunbar, 1988). This progression is similar to the development of Smita's interpreting practices. As the research on scientific reasoning was mostly done in laboratories without capturing how the progression took place over time, this study could be an extension of this area of research by showing how

students' inscriptional practices evolved in classroom settings. Possible explanations of the progression in students' interpreting practices might be their multiple exposures to inscriptional activities, the teachers' ongoing scaffolds, and their cognitive development.

Teachers: A Cultural Mediator between Two Communities

At the end of the water quality unit, the use of data tables and graphs was embedded in students' investigation and became an integral part of inquiry as students were capable of using these inscriptions to record data, analyze data, and present findings without teachers' prompts. During interviews, students voluntarily used data tables and graphs to organize information and present findings. These findings suggest that in this inquiry-based learning environment, some inscriptions and associated practices were recognized and internalized by students. Using these inscriptions became part of classroom culture (Kelly & Chen, 1999; Kelly & Green, 1998) that matched with those in the community of scientists as proposed by National Research Council (1996). What was the teachers' role in creating such a learning community? A discussion of the teachers' role in this learning environment might explain the positive trend related to students' development of competent inscriptional practices.

Research on teachers' conceptions about the nature of science has indicated that teachers' understandings, interests, attitudes, and classroom activities influence student learning to a large extent (Akerson, Abd-El-Khalick, & Lederman, 2000; Lederman, 1992; Pomeroy, 1993). Teachers are interpreters of developed curricula (Lederman, 1992) and mediators between a learning community and the community of scientists (Kelly & Green, 1998). As the water quality curriculum was developed and enacted by the teachers participating in the study, they socialized these seventh graders to the norms and expectations of the scientific community through their teaching practices such as embedding inscriptional activities in investigations,

privileging the use of inscriptions, engaging students in authentic practices, and supporting students' inquiry process with inscriptions. In the quote below, Andrea indicated the differences between her students and scientists in their understandings about concepts and inquiry processes and explained what they did in order to help students do what scientists do.

I'd like to think that we're mirroring what scientists do here in class, but, of course, our students are novices, and so they don't have the rich understanding of things. They, you know when they approach the idea of designing an experiment, they're clueless. ... That's why we take them through that slowly so that over the course of two years, they should feel pretty confident in terms of what they're doing or the same thing that scientists do, of course, not as a sophisticated level. (Teacher's interview #2)

Previously, we indicated that the cultural negotiation process (Bruner, 1990) between a local group and the community of scientists should be seriously considered. The differences in tasks, understandings, and value systems between the two communities should be considered so that students could benefit from learning activities that mirror scientists' practices. The teacher's quote above indicated that the teachers (as curriculum designers) recognized the differences between students and scientists and scaffolded students to experience what scientists do based on their understandings about students' learning trajectories and about the discipline of science.

Therefore, although this study focused on students' inscriptional practices rather than teaching practices, the findings suggest that the teachers' understandings about the discipline of science and the differences between the two communities might explain the success of creating a culture that encouraged the development of competent inscriptional practices. Future research on teachers' conceptions about the discipline of science and their pedagogical practices would advance understandings of how teachers' perceptions about scientific practices interact with the construction of a culture of inquiry.

Designing a Learning Environment for Developing Competent Inscriptional Practices

Based on the studies of college students and scientists, science education researchers (Bowen et al., 1999; Kozma et al., 2000; Roth & McGinn, 1998) call for educators to design a learning environment in which students have opportunities to develop competent and authentic inscriptional practices. These authentic practices share similar characteristics of those demonstrated in the professional scientific community, such as constructing inscriptions to generate patterns in data, interpreting inscriptions created by others, using inscriptions to make predictions and explanations, and identifying and analyzing visual features of an inscriptions. In their study of college students and professional scientists, Bowen et al. (1999) proposed a question for future research: "What kind of features do such learning environments need to have so that students' competencies [in inscriptional practices] are developed?" (p. 1040). As the level of students' participation in constructing and interpreting practices increased over time, this study provides insight into this question.

The use of inscriptions should not be assigned as isolated tasks. Rather, to help students understand the relationships among inscriptions, concepts, and inquiry, the use of inscriptions should be embedded in the inquiry process. In doing so, students have a need to learn (Blumenfeld, Marx, Patrick, Krajcik, & Soloway, 1997), realize the purposes of using inscriptions, and construct the meanings of inscriptions based on the context (Greeno & Hall, 1997). Additionally, inscriptions are traditionally viewed as tools to present findings and analyzing data (Brasell & Rowe, 1993; McKenzie & Padilla, 1984; Preece & Janvier, 1992). According to the analysis of classroom videos, however, the seventh graders in this study demonstrated inscriptional practices in various inquiry areas, including making predictions, developing questions, and planning and carrying out investigations. Constructing and

interpreting inscriptions in different inquiry areas provided students with opportunities to decide how and what inscriptions should be used based on the characteristics of the inscriptions and the purposes of reasoning. Different inquiry areas could provide meaningful contexts for students to engage in a variety of inscriptional practices.

Additionally, students' initial enactment of inscriptional practices requires co-participation of more competent others. The findings suggest that teachers' scaffolds were crucial to facilitate students' engagement in inscriptional practices. This finding is supported by other studies conducted in a guided-inquiry environment (e.g., Krajcik et al., 1998; Tabak, 1999; White & Frederiksen, 1998). Scaffolds are not necessarily in a form of discursive interactions between teachers and students. They could be provided by curriculum materials or learning technologies (Hoffman, Wu, Krajcik, & Soloway, 2003). In this study, guideline sheets (Figure 6) prepared by teachers played a role of scaffolding because they provided a series of questions or guidelines that structured a difficult inscriptional activity and allowed students to participate in the activity without the presence of teachers.

Two features of the curriculum design, sequencing inscription-related activities and engaging students in using inscriptions in an iterated matter, seem to promote the enactment of inscriptional practices. Sequencing and iterating instructional tasks are not new ideas in curriculum development (Krajcik, Czerniak, & Berger, 1999). Using sequencing as a type of scaffolding allows students to focus on completing one sub-task at a time and makes a complex task feasible. Also, it is unlikely that students could internalize the sequence by only one exposure, so engaging in inscriptional activities in an iterated matter could help develop thematic continuity of content and practice (Tabak, 1999). Yet, sequencing a task is different from a step-by-step activity in which teachers gave the instruction about how to carry out the activity and

every student performs the same activity (Krajcik et al., 1999). The four steps of data analysis suggested by the teachers in this study were procedural as well as conceptual. Each step required students to use social, conceptual, and material resources to accomplish it (White & Frederiksen, 1998). Students not only learned how to interpret inscriptions, but also what to interpret from the inscriptions by intentionally abstracted certain information from the inscriptions. Also, iterating tasks is not simply repeating what students have done before. In each sub-unit, for example, students were assigned tasks with different levels of complexity. Iterating inscriptional activities maintained continuity of practice and helped students demonstrate more sophisticated practices. These findings about the use of resources and the curriculum features provide insight into the design of a learning environment in which students have opportunities to develop competent and authentic inscriptional practices.

Conclusion

Expanding upon early research on students' learning of inscriptions, this study shows that seventh graders could demonstrate competent inscriptional practices when they were scaffolded by the teachers and the curriculum in a learning environment where the inscriptional activities were sequenced, iterated, and embedded in scientific inquiry. Using inscriptions in science classrooms could help students plan their investigation, review the inquiry process, and discuss related concepts. The development of students' inscriptional practices documented in this study could inform theories about social practices, learning communities, scientific reasoning, and science inquiry. The findings about the curriculum features provide insight into the design of a learning environment in which students have opportunities to develop competent and authentic inscriptional practices.

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Footnotes

¹ Pseudonyms for teachers and students that maintain their gender and ethnic are used throughout this paper.

² In this study, we focus on the findings of constructing and interpreting practices. Detailed descriptions and discussions of other inscriptional practices, i.e., reasoning, presenting, and critiquing practices, are documented by Author (2002).

³ Using Lincoln and Guba's (1985) four dimensions with other researchers' recommendations (e.g., Jick, 1979), Moschkovich and Brenner (2000) reframed the traditional concepts of internal validity, external validity, reliability, and generalizability into credibility, transferability, dependability, and confirmability.

Table 1

Inscriptional Practices, Definitions, and Examples

Practice	Definition	Examples
Constructing	Constructing practices involve class members' discourse, actions, behaviors, and information used when they plan and use instruments, (e.g., paper and pencils, computers, or technology) to generate, record, and transform signals or readings into a materialized form.	Constructing practices include planning and designing inscriptions (e.g., graphs and tables), recording readings, transforming one inscription into another, incorporating and combining several inscriptions into webpages, capturing visual information in drawings and pictures, and modifying the inscriptions that are already created.
Interpreting	Interpreting practices involve class members' discourse, actions, behaviors, and information used when they generate meanings out of an inscription and make sense of the phenomena, concepts or data represented by an inscription.	Interpreting practices include examining the consistency of data, identifying patterns from graphs, searching for reasons to explain patterns and data, comparing findings to predictions and standards, and providing meanings to components of an inscription, e.g. relationships in a model.
Reasoning	Reasoning practices involve class members' discourse, actions, behaviors, and information used when they use inscriptions as an initiator of discussions, a mediator between concepts and phenomena, a piece of evidence to support their arguments, or a resource to support their inquiry.	Reasoning practices include using inscriptions (e.g., digital pictures, graphs, tables, and maps) to make predictions, support arguments, illustrate ideas, conceptualize a phenomenon, manipulate inscriptions to gain new understandings, and draw conclusions.
Presenting	Presenting practices involve class members' discourse, actions, behaviors, and information used when they display their own inscriptions to a group of students or the whole class.	Presenting practices include describing and providing meanings to the components of an inscription, explaining the relationships among the components, elaborating on the ideas based on the feedback, and clarifying confusions in a follow-up discussion
Critiquing	Critiquing practices involve class members' discourse, actions, behaviors, and information used when they draw on particular concepts and concerns as criteria to make comments, give feedback, and determine the quality or accuracy of an inscription.	Critiquing practices include asking for clarifications and explanations, indicating missing components, suggesting a change of components and categories, and asking for an answer and a conclusion based on the inscription presented.

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Table 2

Inscriptions Used and Inscriptional Practices in the Water Quality Unit

Inscription	Number of class period							
	Constructing Practice				Interpreting Practice			
	WQ I	WQ II	WQ III	Total	WQ I	WQ II	WQ III	Total
Graph	5	2	9	16	2	1	2	5
Data table	13	0	1	14	3	0	0	3
Webpage	0	0	12	12	0	0	0	0
Model	6	3	0	9	4	3	0	7
Digital picture	2	1	4	7	0	0	0	0
Stream drawing	3	0	0	3	0	0	0	0
Table	1	0	0	1	0	0	0	0
Chemical representation	0	0	0	0	2	0	0	2
Map	0	0	0	0	1	0	0	1
pH scale	0	0	0	0	0	0	0	0
Total	30	6	26	62	12	4	2	18

Figure Captions

Figure 1. Cynthia's data table for the pH experiment: (a) a scanned image taken from her notebook, and (b) a reproduction of the table.

Figure 2. A reproduction of Nathan's pH graph in WQ I. The background of the graph is color-coded. Different color areas show the ranges of water quality standards (7: excellent; 6-8: good; 8-9 and 5-6: fair; >9 and <5: poor).

Figure 3. The longitudinal graph drew by the teacher on the board: (a) A snapshot taken from the class videotape, and (b) a reproduction of the graph.

Figure 4. The class data table used to share pH data collected from groups: (a) A snapshot taken from the class videotape, and (b) a reproduction of the table.

Figure 5. Ally and Denny's longitudinal graph of conductivity downloaded from their webpage.

Figure 6. The guideline sheet for students' stream longitudinal analysis.

Substance	pH of substance
Average	Prediction

(a)

Substances	PH of substance				
	1	2	3	Average	Prediction

(b)

Figure 1. Cynthia's data table for the pH experiment: (a) a scanned image taken from her notebook, and (b) a reproduction of the table.

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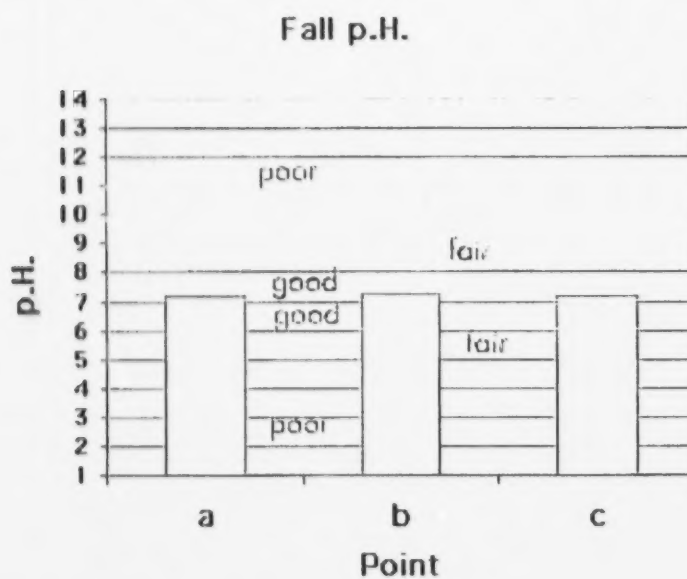


Figure 2. A reproduction of Nathan's pH graph in WQ 1. The background of the graph is color-coded. Different color areas show the ranges of water quality standards (7: excellent; 6-8: good; 8-9 and 5-6: fair; >9 and <5: poor).

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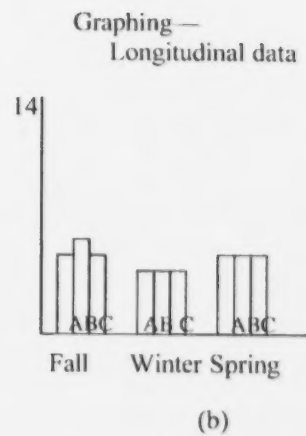
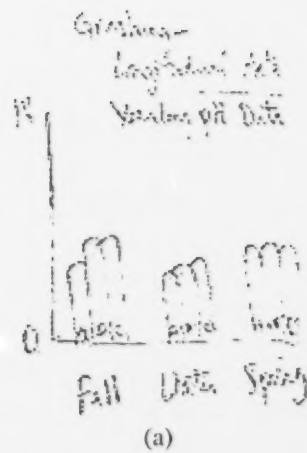


Figure 3. The longitudinal graph drew by the teacher on the board: (a) A snapshot taken from the class videotape, and (b) a reproduction of the graph.

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	1	2	3	4	5
Ammonia	10.03	10.81	9.98	10.02	9.9
Antifreeze	10.07	10.86	---	9.74	9.86
Windex	9.91	10.27	9.58	9.58	9.59
Down	7.54	6.36	7.45	7.15	6.76
Sally's water	9.36	9.8	9.25	9.18	9.25
Acid rain	2.76	2.39	2.40	2.56	2.95
Tide	10.04	10.54	10.09	10.35	9.96
Sand	8.5	8.31	8.61	8.73	8.43
Distilled water	4.07	4.25	4.57	4.26	4.61
Peat moss	5.7	5.45	4.23	5.13	5.11
Salt	6.29	7.16	5.0	7.91	7.12

OCT 10 2000
10:37:44AM

(a)

Group	1	2	3	4	5	6
Ammonia	10.03	10.81	9.98	10.02	9.9	9.2
Antifreeze	10.07	10.86	---	9.74	9.86	9.50
Windex	9.91	10.27	9.58	9.58	9.59	9.13
Down	7.54	6.36	7.45	7.15	6.76	5.92
Sally's water	9.36	9.8	9.25	9.18	9.25	8.96
Acid rain	2.76	2.39	2.40	2.56	2.95	1.72
Tide	10.04	10.54	10.09	10.35	9.96	9.33
Sand	8.5	8.31	8.61	8.73	8.43	8.12
Distilled water	4.07	4.25	4.57	4.26	4.61	4.10
Peat moss	5.7	5.45	4.23	5.13	5.11	4.89
Salt	6.29	7.16	5.0	7.91	7.12	7.23

(b)

Figure 4. The class data table used to share pH data collected from groups: (a) A snapshot taken from the class videotape, and (b) a reproduction of the table.

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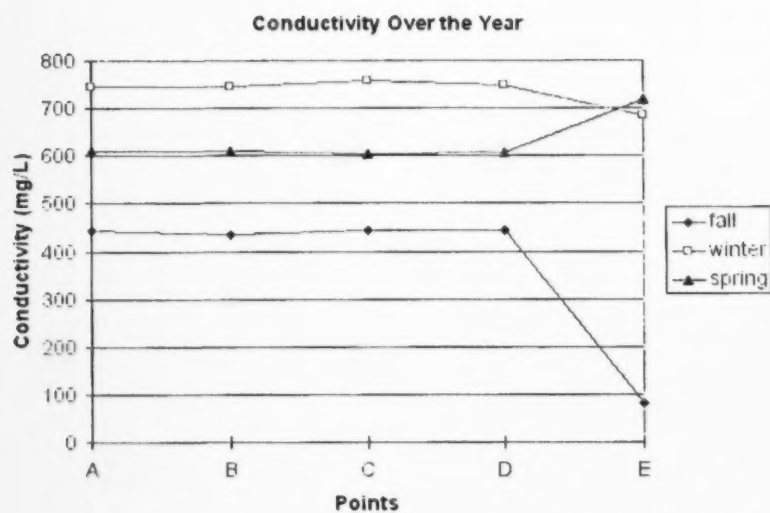


Figure 5. Ally and Denny's longitudinal graph of conductivity downloaded from their webpage.

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7th Grade - Water Analysis
May-June 2001

Stream Longitudinal Analysis

You all need to know how very proud we are of you and your progress as scientists! It has been a pleasure watching you develop very important science skills. We hope that you feel more confident in yourselves and can appreciate all that you have learned.

In the next week you and your partner will be creating a web page to explain your study of water quality data throughout this year. To prepare for that, you have been assigned the construction of graphs that contain data for each test you do for fall, winter and spring over the past few days. Your 5 graphs will be due this Friday, May 25. This Thursday and Friday in class you will be given class time to discuss these analysis with your partner in preparation for the analysis you will begin writing for each test starting next Tuesday night. You will receive a calendar in class on Tuesday, which will include what our class work, and homework is. As always please be sure to double check that you what is expected in the next two weeks. If you have any questions please be sure to ask for clarification.

Longitudinal Analysis: Looking at data from fall, winter and spring.

Water quality tests: Look at each of the test results (temperature, DO%, conductivity, turbidity and pH using your graphs) and see if there are any patterns. Are there changes from season to season? If yes, what might explain these changes? Do the changes increase or decrease water quality? Why?

____ Introduction to your analysis.

____ Report a summary of your data for fall, winter and spring (with more emphasis on your spring data.

____ Refer to the standards for each test to determine the quality of the stream.

Look for patterns: ____ a. Static or dynamic through the seasons. Why or why not?

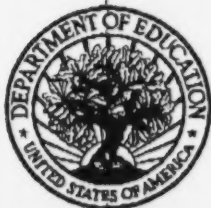
____ b. Refer to background information and physical data

Physical data: When referencing you physical data in your analysis for each test, look at depth, width and stream flow. How are they the same/different over a period of time? Why did or didn't they change? (What is an explanation for these changes if they occurred?). Look at the weather and other information you have. How might these contribute? Has

Conclusion: Remember our original question? Restate it and tell us your overall prediction. Present a brief summary of your data for the year. Based on all of your data for the entire year write a few conclusions about the health of the stream. You may think of it as a "report card" for the stream quality based on grades from the data you have and the background you know about what the data means. Include an overall grade for the stream with reason to back it up.

Figure 6. The guideline sheet for students' stream longitudinal analysis.

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